Radio Science Support

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Support provided by the DSN to radio science experiments is summarized for the period of January–October 1973. The 26-m and 64-m antennas were used to conduct Very Long Baseline Interferometry (VLBI) observations of pulsars, quasars, and radio galaxies. Radio astronomy scientists used the 64-m antenna at Goldstone, California, at 2.3 and 8.4 GHz to measure the confusion distribution of weak radio sources, to determine the population of radio sources near certain spiral galaxies, and to study emissions from various pulsars. This radio telescope was also used at 14 GHz to search for interstellar molecules and to study radio emission from Jupiter and Uranus; pulsar observations were also conducted at this frequency. The high-power transmitter capability of the Goldstone 64-m antenna was also used for radar ranging to the planets Venus, Mercury, and Mars for the purpose of improving the ephemerides of Venus and Mercury in support of the Mariner Venus/Mercury 1973 Project and to obtain surface height and roughness data of Mars in support of the Viking Mars 1975 Project. Some radio science-related DSN development activities were also carried on; these included attempts to obtain radar return from Saturn and/or its rings and to search for radar reflection from Jupiter or its moon Ganymede. In addition, VLBI techniques were used to make measurements between California and Spain to determine Deep Space Station locations, Earth polar motion, and Universal Time to higher precision. A bibliography of papers published by radio scientists using data obtained with DSN facilities is included.

I. Introduction

The 26- and 64-m antenna stations of the DSN have been used for several years to support radio science experiments. NASA, JPL, and university scientists have used key DSN facilities whose particular and unique capabilities were required for the performance of the experiments. A Radio Astronomy Experiment Selection (RAES) Panel was formed in 1969 in order to formalize the method of selecting the experiments of non-NASA experimenters. No charge is made for use of the standard DSN facilities and equipment; any special equipment required must be provided by the experimenters. A summary of all previous activity is reported in Refs. 1–10.

II. Radio Science Operations

Radio science support provided by the DSN during FY 1973 is summarized in Table 1. The total support, 1378 hours, represents 15.6% of the available antenna time. Most of the time shown for support of RAES Panel experiments was devoted to support of the Quasar Patrol (287 hours). The largest user of time among experiments sponsored by the Office of Space Science (OSS) was the radar ranging on Venus and Mercury in support of the Mariner Venus/Mercury 1973 Project (331 hours). Interstellar microwave spectroscopy (a search for interstellar molecules) received 232 hours; the remainder of the time was devoted to observations of Jupiter and Uranus and of pulsars. The

activity sponsored by the Office of Tracking and Data Acquisition (OTDA) consists only of the radio science-related elements of DSN Development.

Seventy-five hours were devoted to the application of VLBI techniques to the determination with higher precision of the Deep Space Station locations, Earth polar motion, and Universal Time. The remainder of the time was devoted to the development of weak signal processing techniques in observations of Jupiter, Saturn, and asteroids. Those months in which RAES experiments received fewer or no hours of support are those in which either the time was preempted by the Mariner 9 project or DSS 14 was out of service during major upgrading operations. During the former periods, other radio science experiments were scheduled outside the MM'71 view periods.

The experiments supported since the last report (Ref. 10) are shown in Table 2. A 24-h Quasar Patrol has been scheduled at least once per month, the observations generally being made every other month by one of the groups of investigators. Other RAES Panel experiments were scheduled as time was available. These included some VLBI observations as well as radiometer-type measurements from DSS 14 alone, such as measurement of confusion distribution and mapping of spiral galaxies. In April, the first use was made of the 64-m antenna in Australia in a VLBI observation with the 26-m antenna at Goldstone. In July, radar observations of Mars were resumed in support of the Viking Mars 1975 Project. The purpose of the measurements is to obtain surface height and roughness data of the planet to assist in the determination of landing sites. The radar observations resulted in a detection of the rings of Saturn (Ref. 41).

III. Publication of Results

As the radio science experiments have been evaluated and results have been published, the various papers resulting have been collected (identified in this report as Refs. 2–10). A few older papers previously not identified, and many new papers published since the last report, are shown in Refs. 11–41. References 11–23 set forth results of VLBI observations up to about the time the Quasar Patrol was formally established. Initially these observations were made on the California–Australia baseline at 2.3 GHz (Refs. 14 and 15).

The VLBI observations between Goldstone and the National Radio Astronomy Observatory (NRAO) antennas in West Virginia and the Haystack antenna in Massachusetts were employed in the first transcontinental uses of the DSN facility, first at 2.3 GHz, and later at 8.4 GHz (Refs. 11–13, 16, and 17). In 1971, these baselines were augmented by cooperative, simultaneous observations with the Crimean Astrophysical Observatory (Refs. 18–21). Early in 1972, the Quasar Patrol was established to provide a systematic approach in the use of DSN facilities to observe quasars and radio galaxies. The Patrol consists nominally of a regular, 24-h observation period, approximately once per month. The observations are made by the various investigating groups indicated in Table 2. A summary of the results obtained by that time was presented in December of 1972 (Ref. 24).

Reference 26 is an overall view of the subject of extragalactic radio sources with an indication of the role played by DSN-type instrumentation and investigation of compact radio sources. References 27–29 report on the measured apparent changes of some sources and verify what had been the anticipated need for the regular observations provided by the Quasar Patrol in order to detect such changes properly.

Additional investigations into the scientific questions posed by these radio sources are indicated in Refs. 30–32. These observations do not use VLBI techniques, but rather depend upon the extreme sensitivity of the 64-m antenna and the noise-adding radiometer to search for very weak radio sources in certain regions. References 33 and 34 are also papers resulting from RAES Panel–supported experiments. Reference 35 results from the OSS-supported investigation in the search for interstellar molecules. References 36-40 result from planetary astronomy observations supported by OSS. Detection of the rings of Saturn by radar (Ref. 41) results from a DSN development activity in detecting and processing weak signals.

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    2. Whiting, A. R., et al., "Astrometric Results from VLBI Observations of Extragalactic Radio Sources."

    3. Fanselow, J. L., et al., "Radio Interferometric Measurements of Universal Time Variations and Equatorial Components of an International Baseline."

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Table 1. DSN support to radio science experiments—FY 1973

Month	Support time, h, for radio science experiments				Total
	RAES	OSS	OA	OTDA (DSN development)	
July	46	64	–	16	126
August	49	86	15	18	168
September	–	89.5	–	–	89.5
October	32	108	15	–	155
November	46.5	103	16	–	165.5
December	17	76.5	–	47.5	141
January	–	26.5	–	20	46.5
February	48	16.5	–	–	64.5
March	25	8	–	–	33
April	29	73	–	8.5	111.5
May	25	95.5	–	25.5	146
June	44	80	–	8	132
Totals	362	826.5	46	143.5	1378

Table 2a. Radio science experiments involving 64-m and 26-m antenna facilities—RAES Panel

Experiment	Purpose	Experimenter	DSN facility	Dates
Quasar Patrol	To make detailed measurements on radio galaxies and quasars at 2.3, 7.8 and 15.6 GHz; to search for weak compact sources in the nucleus of extended radio galaxies and quasars; to monitor time variations in fine structure and apparent positions of quasars	Group A D. S. Robertson, WRE[a] A. J. Legg, WRE J. Gubbay, WRE A. T. Moffet, Caltech G. Nicholson, CSIR[b]	DSS 43 (64-m antenna in Australia) and 26-m antenna at Goldstone	April 2, 1973
		Group B J. J. Broderick, NAIC[c] B. G. Clark, NRAO[d] M. H. Cohen, Caltech D. L. Jauncey, Cornell Univ. K. I. Kellerman, NRAO G. H. Purcell, Caltech D. B. Shaffer, Caltech	DSS 14 (used with MIT Haystack and NRAO 42-m antenna)	October 23, 1972 November 25, 1972 February 4, 1973 April 26, 1973 June 22, 1973 September 17, 1973
		Group C T. A. Clark, GSFC[e] R. M. Goldstein, JPL H. J. Hinteregger, MIT C. A. Knight, MIT G. E. Marandino, Univ. of Maryland G. Resch, Univ. of Maryland A. E. Rogers, Haystack Observatory I. I. Shapiro, MIT A. R. Whitney, MIT	DSS 14 (used with MIT Haystack and NRAO 42-m antenna)	November 7, 1972 February 3, 1973 March 31, 1973 May 17, 1973 August 13, 1973 October 14, 1973
Very Long Baseline Interferometry (medium data bandwidth, S-band)	To determine angular size of radio sources	J. Gubbay, Univ. of Adelaide A. Legg (Space Research Group, WRE) D. Robertson (Space Research Group, WRE) A. Moffett, Caltech B. Seidel, JPL	DSS 14 (64-m antenna) and DSS 41 (26-m antenna)	June 12, 1971 January 25, 1972 February 21, 1972 June 19, 1972
Weak radio source observations	To measure the "confusion distribution" of weak radio sources at 2.3 GHz	D. L. Jauncey, Cornell Univ. M. J. Yerbury, Cornell Univ. J. J. Condon, Cornell Univ. D. J. Spitzmesser, JPL	DSS 14	June 5, 12–1972 July 5, 13–1972 December 6, 18–1972 April 13, 1973
Very Long Baseline Interferometry (2295 MHz, NRAO recording terminals)	High-resolution studies of extragalactic radio sources	J. Broderick, NRAO B. Clark, NRAO M. H. Cohen, Caltech D. Jauncey, Cornell Univ. K. Kellermann, NRAO	DSS 13 (and NRAO 43-m antenna) Plus 100-m antenna in Effelsberg, Germany	August 7, 1971 July 2, 1973 June 18, 19, 20, 21–1973
Spiral galaxy mapping	To determine population of nearby radio sources in certain spiral galaxies	H. Arp, Hale Observatories	DSS 14	October 4, 7, 13, 20, 27–1971 December 8, 1971 April 16, 1972 June 2, 14–1973 August 1, 31–1973

[a]Weapons Research Establishment.
[b]Commonwealth Scientific and Industrial Research.
[c]National Astronomy and Ionospheric Center, Arecibo, Puerto Rico.
[d]National Radio Astronomy Observatory.
[e]Goddard Space Flight Center.

Table 2b. Radio science experiments involving 64-m and 26-m antenna facilities—OSS experiments

Experiment	Purpose	Experimenter	DSN facility	Dates
Interstellar microwave low-noise spectroscopy	To search for interstellar molecules at 14 GHz	S. Gulkis, JPL T. Sato, JPL B. Zuckerman, Univ. of Maryland D. Cesarsky, Caltech J. Greenstein, Caltech	DSS 14	April 2, 10, 18–1972 May 2, 6, 14, 17–1972 June 4, 19–1972 August 5, 1972 September 5, 14, 19–1972 October 10, 17, 27, 30–1972 November 2, 10, 11, 17, 23, 26, 29–1972 April 7, 16–1973 May 2, 12, 19–1973 June 3, 12, 23, 26–1973 July 12, 25–1973 August 11, 1973
Planetary radio astronomy	To study radio emissions of Uranus and Jupiter at 14 GHz	S. Gulkis, JPL B. Gary, JPL M. Klein, JPL M. Jansen, JPL Resident Research Associate E. Olsen, JPL Resident Research Associate P. Rosenkranz, JPL Resident Research Associate	DSS 14	April 29, 30–1972 July 14, 1972 August 3, 1972 September 7, 21, 28–1972 October 3, 4, 21, 28, 31–1972 December 20, 1972 April 3, 20–1973 July 5, 16–1973 August 17, 31–1973 September 11, 1973
Pulsar observations	To study emissions from various pulsars at S-, X- and K-bands	G. Downs, JPL G. Morris, JPL P. Reichley, JPL	DSS 14	November 18, 21, 30–1972 December 1, 8, 21–1972 January 6, 14–1973 February 2, 1973 April 14, 22–1973 May 4, 5, 26–1973 June 3, 4, 10, 15–1973 July 7, 8, 14–1973 August 1, 9, 20–1973 September 10, 1973
Venus/Mercury radar ranging	To provide improved ephemerides of Venus and Mercury for Mariner Venus/Mercury 1973 Project	J. Lieske, JPL R. Goldstein, JPL	DSS 14	September 1, 15, 19, 26–1972 October 3, 10–1972 November 24, 28–1972 December 1, 5, 8, 20, 26–1972 January 10, 1973 March 27, 1973 April 3, 13, 20, 27–1973 May 4, 11, 16, 25–1973 June 1, 8, 15, 22, 28–1973 July 7, 10, 13, 18, 21, 24, 27, 31–1973 August 6, 15, 20, 27–1973 September 4, 10, 24–1973 October 8, 15, 22–1973
Mars radar	To obtain surface height and roughness data of Mars in support of the Viking Mars 75 Project	R. Goldstein, JPL G. Morris, JPL	DSS 14	July 12, 18, 21, 24, 27, 29–1973 August 2, 6, 10, 15, 18, 21, 24, 28–1973 September 1, 4, 8, 12, 15, 22, 29–1973 October 4, 5, 12, 15, 19, 22, 23, 24–1973

Table 2c. Radio science experiments involving 64-m and 26-m antenna facilities—OTDA–DSN development (radio science-related)

Experiment	Purpose	Experimenter	DSN facility	Dates
Saturn radar detection	Attempt to obtain radar return from Saturn and/or its rings to demonstrate ultra-weak signal detection techniques	R. Goldstein, JPL G. Morris, JPL	DSS 14	December 4, 5, 28, 29–1972 January 4, 5–1973
Platform parameters	To investigate VLBI techniques for determining station locations, polar motion, and universal time to higher precision	J. Fanselow, JPL M. Slade, JPL J. Thomas, JPL J. Williams, JPL D. Spitzmesser, JPL	DSS 14 DSS 62	April 30, 1973 June 11, 1973 July 20, 1973 September 8, 1973
Asteroid radar detection	To attempt to obtain a radar echo from a recently discovered asteroid	R. Goldstein, JPL	DSS 14	May 21, 22, 23–1973
Jupiter radar detection	To search for radar reflection from Jupiter or its moon Ganymede	R. Goldstein, JPL G. Morris, JPL	DSS 14	July 7, 15, 26–1973 August 3, 1973 September 10, 14, 16, 20–1973